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Method and Device for Reducing Pressure Fluctuations in a Suction Pipe of a Water Turbine or Water Pump or Water-Pump Turbine

The invention relates to a turbine or pump or pump turbine, particularly to the suction pipe thereof which serves for guiding the water flowing out of the turbine to the downstream water. The invention primarily relates to Francis type machines, but also Kaplan type turbines may come into consideration.

Regarding water turbines such as Francis turbines there is an increasing demand for higher efficiencies as well as for an extended range of operation as well as for a higher flexibility regarding the rate of flow between partial load and overload. The efficiency should be high over the whole range of operational parameters, and at the same time the vibration of the turbine should be low.

The adjustment of Francis turbines to variable operational parameters is made by respective positioning of guide vanes. Nevertheless there are instable flow conditions, particularly at partial load, which result in heavy vibrations at the turbine. As a consequence, there may occur damages to specific components, particularly in case the characteristic frequencies of such components coincide with the said frequencies. Also, vibrations of the said kind may be particularly disadvantageous with large machines in that the said vibrations may affect the electric network. Rotational instabilities will be fed into the electric power supply via the generator, thereby resulting in voltage fluctuations. This necessitates disadvantageous limitations of the operational range of the turbine. Critical partial load ranges during start up of the turbine have to be run through rapidly.

When operated optimumly, the water flows from the inlet gates of a Francis turbine axially symmetrically into the runner, where it is deviated by the guide vanes such that it flows axially into the suction pipe and further to the downstream water. The flow in the suction pipe at optimum conditions will be irrotational. At operational conditions of the turbine outside of the optimum, however, there will be torsion of the flow downstreams of the runner. There is no firm knowledge of the

dependence between the rotational component of the flow in the suction pipe and the vibrations of the machine. For stabilizing the flow in the suction pipe and for suppressing the torsion guide fins were used, arranged along the suction pipe. Such guide fins may be oriented in the axial direction. Thereby the flow torsion in the suction pipe will be suppressed, but at the same time the efficiency will be lowered.

To solve the said problem, variable guide fins are used, which according to the flow conditions may be moved in and out. Further, there are used guide fins oriented parallel to the wall surfaces of the suction pipe in order to stabilize the flow by avoiding the separation of the flow. However, also structures of the said type will reduce the efficiency of the turbine. Further, fixed as well as variable finns will increase the costs of manufacture and maintenance of the turbine.

A further approach for the reduction of a torsion of the flow and its detrimental effect under partial load conditions is to feed air or water into the non-stable flow. There have become known structures whereby air is blown into the runner or into the suction pipe either from the wall of the suction pipe or from the axis of the runner.

Further, it has become known to arrange a chamber filled with water or with air around the suction pipe, which chamber communicates with the flow in the suction pipe by openings in the suction pipe wall. Thereby, air respectively water is introduced respectively removed depending on the pressure conditions in the suction pipe flow. Here again, the costs of manufacture are increased by the said pressure chamber as well as by a respective control unit for the pressure in the chamber.

It is the objective of the invention to provide a suction pipe for a Francis turbine which develops advantageous over the prior art. More in detail, the suction pipe should minimize the effect of pressure variations such as occur at partial load

conditions. The said objective will be achieved by a suction pipe according to claim 1.

The inventors have acknowledged that with a Francis turbine under partial load conditions there will be created a zone of recirculation downstreams of the runner. Within the said zone of transition and the main flow there are heavy gradients of velocity. Hydrodynamic instabilities of the Kelvin-Helmholtz-type will result in the formation of vortexes which due to the overall rotation of the flow comprise a rotative component. A rotating vortex of the said type will result in a rotating pressure which in the region of the elbow of the suction pipe generates a force acting in the axial direction, and further results in pressure variations which also act in the axial direction and therefore in the direction of the turbine. It is further possible that such axial pressure variations in combination with the helically shaped vortex – called „rope" – will result in boundary layer burbling at the wall of the elbow, thereby increasing the effect of the axially acting pressure variations. This explains the generation of pressure variations in the suction pipe depending on the rotational speed of the runner.

A further component of so-called stochastic pressure variations may be developed by the fact that due to the helical vortex rope local pressures below the vapour pressure will be created, thereby leading to cavitation. Additional pressure pulses will occur upon bursting of the cavitation blisters.

According to the invention there is arranged in the suction pipe an elongated displacement body. The upstream end thereof is in the vicinity of the hub of the runner.

The displacement body may be rotationally symmetrically, e. g. cylindrical. Also, it may have the shape of a truncated cone which tapers in respectively against the direction of flow. It is arranged such that its outer surface is contacted by flowing water. In general, its length axis will coincide with the length axis of the suction pipe.

Numerous embodiments may be possible. The displacement body may e. g. be a projection of the hub of the runner and therefore be part of the hub. Also, it may be located at a minimum distance from the hub. The said distance may be a few millimeters only, e. g. 1, 2, 3, 5 mm, but also 10 to 50 mm.

A further embodiment may consist in making the hub longer as usual, as seen in the direction of flow, e. g. twice or three times or five times as long as what could be deemed usual, so that the hub itself would form the displacement body. A further part will follow, located in the direction of flow. The said further part is independent of the hub, so that the said further part will not rotate.

In such a case, the said further part independent from the hub has to be fixed inside the suction pipe. Such fixing may be done by means of rods arranged perpendicularly to the flow direction at the wall of the suction pipe. The said rods may be arranged radially.

A further particularly interesting approach may consist in journalling the upstream end of the displacement body at the hub of the runner such that the displacement body will be additionally stabilized.

The invention may be used for straight suction pipes as well as for suction pipes comprising an elbow. With suction pipes with an elbow there is an additional possibility of support by fixing the displacement body in the region of the elbow at the suction pipe respectively at the foundation thereof.

The invention as well as the prior art will be explained more in detail by the figures:

Figure 1	shows an axially cut Francis turbine.
Figure 2	is a numeric flow simulation of the formation of a vortex.
Figure 3	is a suction pipe with a first embodiment of a displacement body.

Figure 4 is a suction pipe with an elbow comprising a second embodiment of a displacement body.

Figure 5 is a straight suction pipe comprising a further embodiment of a displacement body.

Figure 6 is a suction pipe with an elbow comprising a displacement body similar to those according to Figures 3a and 3b.

Figure 7 is a suction pipe with an elbow comprising a displacement body similar to those according to Figures 4a and 4b.

Figure 8 is a suction pipe with an elbow comprising a displacement body which is solely fixed at the elbow.

The Francis turbine according to Figure 1 comprises a runner 1 with a plurality of runner vanes 1.1. The runner is rotatably journalled around runner axis 1.2.

Runner 1 is surrounded by a spiral housing 2. In front of runner 1 there are provided guide vanes 3.

The turbine is provided with a suction pipe 4. Suction pipe 4 comprises a frustroconical inlet portion 4.1 having an axis 4.1.1, followed by an elbow 4.2, which again is followed by a frustroconical outlet portion 4.3.

Inlet portion 4.1 may be shaped asymmetrical with regard to runner axis 1.2. Many variations may be possible. Axis 4.1.1 of inlet portion 4.1 may be offset against runner axis 1.1. Axis 4.1.1 of the inlet portion may be bowed. The wall of inlet portion 4.1 may comprise a bulb at one side thereof, related to the runner axis 1.2. The cross section of inlet portion 4.1 may be different from a circle, e. g. elliptical.

The displacement body 5 according to the invention and the hub of runner 1 may be one single piece, so that displacement body 5 is a projection of the hub in the direction of flow. Therefore, displacement body 5 rotates together with runner 1.

Figure 2 shows a numerical flow simulation of a conventional Francis turbine at partial load operation, thereby demonstrating the velocity distribution of the flow in the suction pipe due to the formation of a helical vortex rope. The vortex rope is disentangled at the elbow, thereby dissipating energy. With the said process due to the rotating pressure field of the vortex rope there will occur pressure variations which will propagate in the axial direction to the turbine. The said instable flow condition causes vibrations, depending on the speed of the runner.

Figure 3a and 3b show the inlet portion of a conventional suction pipe. The said inlet portion is of circular cross section as may be clearly seen from Figure 3b. The axis of inlet portion is straight and coincides with the runner axis.

The hub 1.3 of runner 1 (not shown) is followed by a separate displacement body 5. There is a small distance between hub 1.3 and upper end face 5.1 of displacement body 5. Displacement body 5 is supported by rods 6.1, 6.2, 6.3. The said rods are fixedly connected to the suction pipe 4.1.

Displacement body 5 does not rotate together with the runner 1. As may be seen, its cross section is increasing in the direction of flow.

In contrast to what is shown in Figures 3a and 3b, the displacement body could be located such that there would be no gap between hub 1.3 and displacement body 5, so that the upper face 5.1 of displacement body 5 could act as a support for hub 1.3. This would contribute to the stability and to the secure positioning of displacement body 5.

With the embodiment according to Figures 4a and 4b the suction pipe again comprises an elbow. Thereby, the displacement body 5 is of great axial length. Its upper end is located at the hub of the runner (not shown) of a turbine, e. g. of a turbine of the Kaplan type, and extends to the wall of elbow 4.2, where displacement body 5 is fixed. A further fixation may be necessary, either by means

of rods such as rods 6.1, 6.2 and 6.3, or by journalling the displacement body at the hub of the runner.

In case displacement body 5 is made of one single piece with hub 1.3 of runner 1, so that both parts will rotate together at the same speed, displacement body 5 may be additionally supported at suction pipe 4. The said rods 6.1, 6.2, 6.3 could journal displacement body 5 rotatably. The same applies to the embodiment according to Figures 4a and 4b at elbow 4.2.

The lowermost end of displacement body 5 may have the shape of a shell. Alternatively, it may be rounded.